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ADP013989

TITLE: Characteristics of Spatially-Developed Square Multimode Resonators

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CHARACTERISTICS OF SPATIALLY-DEVELOPED SQUARE MULTIMODE RESONATORS

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ABSTRACT

By mode matching technique a problem of calculation (as well as control) of resonance frequencies and inherent Q-factors of a square resonator with final conductivity of walls loaded by square dielectric samples of complex scalar permittivity and a height, equal to the height of the resonator, has been solved.

INTRODUCTION

When designing electron devices a problem of suppression of unwanted modes arises [1-3]. To solve this problem it is possible to use dielectric absorbing samples of finite dimensions. In the present work the dependence of resonance frequencies and inherent Q-factors of a square resonator against locations of dielectric samples, their dielectric properties and conductivity of the walls is analysed.

FORMULATION OF THE PROBLEM

It is considered a square resonator measured a, l_y, b on axes X, Y, Z accordingly. On the height of the resonator l_y a restriction is imposed, so that in a considered frequency range there is no field variation on this direction. Modes are classified in the XZ-plane. Suppose that m half-waves are kept within X-dimension of the resonator, no one within Y-dimension and n half-waves – within Z-dimension. Under such conditions E-modes (relative to X- or Z-axe) do not arise in the resonator. Identical square dielectric samples are located arbitrarily (the only restriction ensued from the mode matching technique is shown below) within the resonator in parallel to axis Y (fig. 1). The centre of the i-th sample in plane XZ has coordinates r_i and g_i, accordingly. The length and the width of a sample are $2l$ and the height is l_y. The permittivity of the i-th sample is $\varepsilon_i = \varepsilon_i' - j\varepsilon_i''$, the permeability is μ_0. The resonator area outside samples has electrical characteristics of free space. The metal walls permeability is μ_0, conductivity is σ. The dependence on time $exp(-j\omega t)$ is omitted.

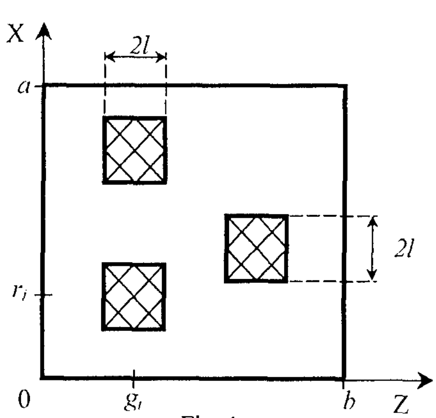

Fig. 1

CALCULATION OF RESONANCE FREQUENCIES

The problem is solved by the mode matching technique. Planes, perpendicular to axis Z and tangent to sides of the samples, separate the resonator into partial regions. Thus dielectric samples should be placed so as not to be intersected by partial region boundaries. Also samples should abut on a partial region boundary solely either from the left or from the right.

Fields are expressed in the usual way. To determine transverse mode functions inhomogeneous partial regions have been broken into partial sub-regions by planes, perpendicular to the axis X and tangent to the sides of the samples.

System of functional equations received as a result of satisfying boundary conditions on dielectric samples was transformed by Galerkin method into the system of homogeneous linear algebraic equations (SLAE). A non-trivial solution of this SLAE can be received when its determinant equals to zero. So, we have an equation of inherent resonance frequencies of the resonator. The order M of the determinant is defined by the following formula: $M = N^*(K-1)$, where N is the number of summand in field expressions taking into account, K is the number of partial regions. So, for a resonator with *8-0-8* working mode, $N = 32$ and $K = 13$ the number M will come to about 400.

To find roots of the equation and to solve the SLAE a computer program has been developed and calculations have been carried out. In a particular case, when the sample of small relative dimensions is in the maximum of electrical field, calculated results agree well with the results, received by the perturbation formula [4].

CALCULATION OF Q-FACTORS

Q-factors have been calculated using electrical conductivity of the walls and imaginary part of the complex permittivity of samples ε''. (The influence of ε'' on resonance frequencies was neglected).

NUMERICAL RESULTS

Calculations have been carried out for resonators with the following dimensions: a = 300,3 mm, b = 300 mm, l_y = 10 mm; a = 600,6 mm, b = 600 mm, l_y = 10 mm; a = 1201,2 mm, b = 1200 mm, l_y = 10 mm. The width a of a resonator is 0,1% larger than its length b in order to segregate such modes as *1-0-2* and *2-0-1* etc. The working mode of the first resonator is *2-0-2*, of the second – *4-0-4*, of the third – *8-0-8*. These resonators are loaded by 3, 8 and 15 identical dielectric samples, accordingly. The size of a sample is $2l$ = 15 mm, the permittivity $\varepsilon = 3 - j0{,}03$. The centre of a sample is situated at the zero field value of the working mode. The metal walls conductivity is $\sigma = 1\cdot10^7$ (Ω·m).

Table 1 shows calculated resonance frequencies f and inherent Q-factors Q of the corresponding *m-0-n* modes. Fig. 2-4 shows Q-factor of different modes as a function of S = lg(tgδ) ($\varepsilon' = 3$) for the resonators with the working modes *2-0-2*, *4-0-4*, *8-0-8*, accordingly. It is evident that proper placing of dielectric absorbing samples (in zero value of the working mode and non-zero value of parasitic modes) allows to make the working mode competitive comparing to parasitic ones.

Table 1

m	*n*	*f*, GHz	Q
working mode *2-0-2*			
1	1	0.6921585	147.941
2	1	1.1047685	292.625
2	2	1.4123048	2171.401
4	4	2.8249589	3339.534
working mode *4-0-4*			
1	1	0.3507614	344.459
2	1	0.5542424	341.500
1	2	0.5556760	456.495
2	2	0.7025874	444.960
3	3	1.0461435	381.377
4	2	1.1133991	909.652
4	4	1.4124070	2359.210

m	*n*	*f*, GHz	Q
working mode *8-0-8*			
1	1	0.1762527	570.377
1	2	0.2788432	725.184
3	1	0.3935335	593.533
3	2	0.4486148	556.588
2	1	0.2785330	618.258
2	2	0.3525262	720.958
3	3	0.5273501	492.919
2	4	0.5571264	768.097
4	2	0.5578370	1026.604
4	4	0.7053032	1238.020
6	6	1.0564086	1042.188
8	8	1.4124681	2361.398

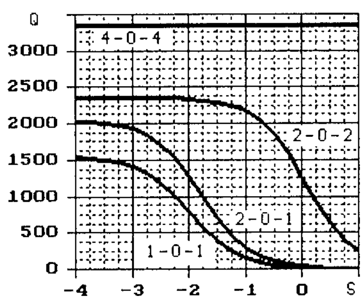

Fig. 2

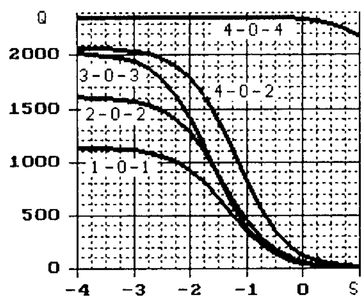

Fig. 3

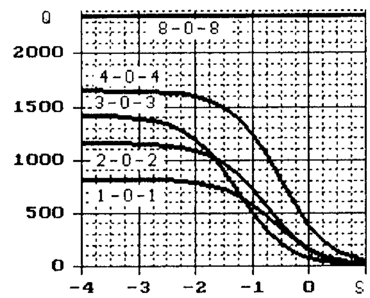

Fig. 4

CONCLUSION

By mode matching technique a problem of calculation of resonance frequencies and inherent Q-factors of the square resonator with final conductivity of walls loaded by square dielectric samples of arbitrary complex scalar permittivity and a height, equal to the height of the resonator, has been solved. Calculated data agree well with already known. A fundamental opportunity to control the resonance frequencies and Q-factors of the resonator by certain placing within it dielectric absorbing samples is presented.

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